Objective. To characterize the types of cognitive and metacognitive processes demonstrated by third-year pharmacy students during a therapeutic reasoning activity.

Methods. A qualitative, descriptive study following a think-aloud protocol was used to analyze the cognitive (analytical) and metacognitive processes observed by third-year pharmacy students as they completed a 25-minute therapeutic reasoning activity. Using a deductive codebook developed from literature about reasoning, two independent coders characterized processes from students’ audio-recorded, transcribed think-aloud episodes while making therapeutic decisions about simulated clinical cases.

Results. A total of 40 think-aloud episodes were transcribed among the cohort. Categorization of the think-aloud transcriptions revealed a series of cognitive analytical and metacognitive processes demonstrated by students during the therapeutic decision-making activity. A total of 1792 codes were categorized as analytical processes, falling into six major themes: 69% gathering information (1232/1792), 13% processing information (227/1792), 7% making assessments (133/1792), 1% synthesizing information (19/1792), 7% articulating evidence (117/1792), and 4% making a recommendation (64/1792). In comparison to gathering information, a much lower frequency of processing and assessment was observed for students, particularly for those that were unable to resolve the case. Students’ movement between major analytical processes co-occurred commonly with metacognitive processes. Of the 918 codes categorized as metacognitive processes, two major themes arose: 28% monitoring for knowledge or emotions (257/918) and 72% controlling the planning of next steps or verification of correct information (661/918). Sequencing the codes and co-occurrences of processes allowed us to propose an integrated cognitive/metacognitive model of therapeutic reasoning for students.

Conclusion. This study categorizes the cognitive (analytical) and metacognitive processes engaged during pharmacy students’ therapeutic reasoning process. The findings can inform current instructional practices and further research into educational activities that can strengthen pharmacy students’ therapeutic reasoning skills.

Keywords: clinical reasoning, therapeutic reasoning, metacognition, think aloud

INTRODUCTION

Clinical reasoning is a complicated topic in the medical literature. This is, in part, because the terminology about how a variety of clinicians make decisions about diagnosis, treatment, monitoring, and resource allocation overlaps.1 Although the reasoning processes have some similarity, among them there appear to be distinct ways of thinking, which may require different ways of educating.

In comparison to diagnostic reasoning, therapeutic reasoning and therapeutic decision-making are less well described in health professions education.1 As the profession most focused on medication use, the field of pharmacy has an opportunity to lead the study of therapeutic reasoning.2-4 Therapeutic reasoning is considered an essential skill of the 21st century pharmacist.2 In fact, Standard 10 of the Accreditation Council for Pharmacy Education’s 2016 Standards emphasizes the importance of a curriculum that applies knowledge and skills to therapeutic decision-making.3

To optimize pharmacy students’ therapeutic reasoning, educators must understand therapeutic reasoning and
how it optimally and sub-optimally occurs. Several theorists propose that reasoning should be understood through the lens of an integrated dual process model of cognition and metacognition.\textsuperscript{5,7} Dual process theory categorizes the cognitive processes involved in decision-making as nonanalytical (referred to as System 1 thinking) and analytical (referred to as System 2 thinking).\textsuperscript{6,8} Nonanalytical processes rely on rich cognitive schema (often referred to as illness scripts) built from experience and knowledge acquisition that are drawn on subconsciously and effortlessly via mechanisms such as pattern recognition.\textsuperscript{8,9} Due to the introspective nature of nonanalytical processes, reliably documenting their presence through observation is challenging. For this reason, our study does not report on cognitive nonanalytical processes. However, it is important to consider the influence of these processes in the overall context of therapeutic reasoning.\textsuperscript{10} In contrast, analytical processes refer to conscious, deliberate thinking such as hypothesis formation and testing.\textsuperscript{8} Often referred to as thinking slow, analytical processes can more reliably be measured through observation. We choose to frame our research using a more contemporary integrated model of dual process theory that highlights the importance of metacognitive processes in addition to analytical and nonanalytical processes. Integrated dual process theory models suggest that the reasoning process is a continuum whereby an individual transitions between nonanalytical and analytical cognitive processes that are controlled and monitored by metacognitive processes.\textsuperscript{5,7} Metacognitive processes occur when the learner plans, monitors, or controls for their cognitive processes. For example, metacognition occurs when someone identifies something they do not know and constructs strategies for troubleshooting.

Our study addresses two gaps in the therapeutic reasoning process literature: the therapeutic reasoning processes of pharmacy students and the investigation of metacognitive processes in therapeutic reasoning. In pharmacy, we identified previous studies exploring the therapeutic reasoning processes of students and practicing pharmacists.\textsuperscript{11-14} These studies used a think-aloud protocol, a survey, and post-interaction interviews to generate new frameworks, identify themes, and explore factors influencing therapeutic reasoning.\textsuperscript{11-14} The only study focused on pharmacy students’ reasoning processes concentrated on ethical decision-making.\textsuperscript{11} Although this is a crucial area, the field would also benefit from exploring pharmacy students’ therapeutic reasoning during management of clinical patient cases.

Outside of pharmacy, researchers have investigated the therapeutic reasoning processes in medicine, nursing, occupational therapy, physical therapy, and more.\textsuperscript{15-22} In the therapeutic reasoning literature, only two studies have focused on metacognitive processes in therapeutic reasoning.\textsuperscript{19,20} Our primary aim was to characterize the types of cognitive and metacognitive processes in third-year pharmacy students’ therapeutic reasoning. By exploring pharmacy students’ therapeutic reasoning processes, schools and colleges of pharmacy can better design curricula, tools, and learning activities to improve students’ therapeutic reasoning processes over time. This study offers a cross section of students’ development of therapeutic reasoning skills. Through this work, we can identify what cognitive and metacognitive processes students use and the characteristics of each process step.

METHODS

In 2019, we initiated a qualitative, descriptive study using a think-aloud protocol to analyze the cognitive processes performed by third-year pharmacy students enrolled in a 12-credit-point, required course of study (Acute Care: Inquiry Cases) at the Faculty of Pharmacy and Pharmaceutical Sciences, Monash University. The Acute Care: Inquiry Cases course was designed using team-based, flipped classroom methods. It was sequenced following a series of organ system–based comprehensive care courses where a uniform model of care (analogous to the Pharmacists’ Patient Care Process in the United States) was instructed.\textsuperscript{23} The course focused on strengthening student problem-solving skills and therapeutic reasoning in the context of acute care conditions. Students were grouped into the same teams of five to six students throughout this course.

One of the formative assessments for each group was the completion of a 25-minute facilitated think-aloud activity during a scheduled two-hour workshop. The group was instructed to choose one student who would lead the think-aloud activity. This lead student was instructed to review a simulated hospital-based clinical case. They were provided a simulated admission note, medication chart, and pathology results relevant to the case. The student was instructed to evaluate the case, identify any associated medication-related problems, and propose therapeutic decisions to resolve such problems. Each case contained one core medication-related problem. Students were instructed to think aloud by verbalizing their thoughts concurrently as they approached the case. During the activity, students were permitted access to the internet and provided hard copies of standard pharmacy reference texts or guidelines.

Each session was facilitated by a practicing pharmacist. The main role of the facilitator was to prompt students to think aloud if there was a pause for longer than 60 seconds. The facilitator was permitted to clarify relevant information about the case that was not readily available.
from the provided resources (eg, clarification about previous control of chronic illness). However, facilitators were instructed to avoid responding to requests for case hints. The student performing the think-aloud activity was permitted 15 minutes to complete the case. During this time, other students within the group were asked to observe the interaction and to refrain from interrupting. At the conclusion of the case, these students received formal feedback from the facilitator about the student’s performance and about the key concepts within the case. Five different cases in total were implemented across the following topics: transplant medicine, stroke, sepsis, acute kidney injury, and inflammatory bowel disease. For each case, optimal therapeutic decisions were determined by the expert case writer and provided to the facilitator.

Prior to the activity, students were informed about the research processes and asked for their consent to participate. Participation meant that their session would be audio recorded, transcribed by a secure third-party company (Rev.com Inc), and the transcripts would be returned to the investigators in a deidentified format for analysis. Approval for this study was granted by the Monash University Human Research Ethics Committee.

The codebook was developed using a semi-inductive approach (Table 1 and Table 2). The investigators developed an a priori codebook adapted from the literature on cognitive (only analytical processes) and metacognitive processes in the context of clinical decision-making, diagnostic reasoning, therapeutic decision-making, and critical thinking in health care. Sample transcripts were analyzed independently by the principal investigators. New codes that did not match well with existing codes were adjusted iteratively through constant comparative discussion until a final consensus was achieved. Two independent coders then coded the audio transcripts from the think-aloud activity using the finalized codebook. Coding was performed using NVivo 12 software (QSR International LLC). Coders convened to calculate the interrater reliability of the codebook by calculating simple agreement and the Cohen kappa (includes a statistical adjustment due to chance). In this study, interrater reliability represents our confidence in the coders applying the same codes to the transcripts. Differences between coders were resolved by adjudication from the principal investigators. Frequency of codes (No. [%]) were used to report a global summary of the cognitive processes observed. We performed an inductive postcoding analysis to categorize each code, and, to develop a model, we mapped the sequencing and co-occurrences of analytical and metacognitive processes. We commenced by listing all major analytical processes chronologically in an event-listing matrix for each transcript. This established a common sequence of cognitive processes to create a preliminary model. We then used an NVivo matrix function to determine where analytical codes overlapped with metacognitive codes. This allowed us to construct a therapeutic reasoning model that described how pharmacy students rationalized treatment options and monitored their thinking processes.

RESULTS

All 40 students leading the think-aloud activity consented to having their session transcribed and included for analysis. A total of 3418 codes were identified and analyzed using the codebook. The codes were categorized into 19 analytical cognitive and five metacognitive processes. The interrater agreement was 88% and the Cohen kappa was 0.76, indicating substantial agreement between the coders. The frequency of codes is summarized in Table 1 and Table 2.

Six major analytical cognitive analytical process themes were observed: gathering information, processing information, making an assessment, synthesizing information, articulating evidence, and making a recommendation. For the first cognitive process theme, gathering information, all students commenced the therapeutic reasoning process by reviewing available provided notes, but then they would go back to this cognitive task afterward to seek medication-related problems or to review their process. Typically, students would then clarify patient case information from the facilitator as a routine task to gather the basic patient details or to guide the next step in gathering information. In addition to case-related information, the therapeutic reasoning process required gathering information from references including standard pharmacotherapy texts. This process was commonly carried out to calculate doses, check interactions, check drug information, and check guideline recommendations. Using references often prompted students to then clarify patient information from the facilitator to confirm facts about the case.

Most students considered the context, simply by reading out loud the provided prompt prior to commencing their therapeutic reasoning process. However, some students considered the context later in the session to help process information and make relevant contextualized decisions (eg, hospital setting).

Regarding the processing information theme, almost all students verbalized the process of recognizing between normal and abnormal values (95%, 38/40). For example, students would comment on the normality of a numerical observation, such as blood pressure or creatinine clearance. Another process observed at this stage was distinguishing between relevant or irrelevant information. This manifested
Table 1. Final Codes, Examples, and Frequencies for Cognitive Codes From a Study of Cognitive and Metacognitive Processes Demonstrated by Pharmacy Students When Making Therapeutic Decisions

<table>
<thead>
<tr>
<th>Codes</th>
<th>Participant quotes</th>
<th>Frequency (N=3418), No. (%)</th>
<th>Literature supporting code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathering information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consider the context</td>
<td>“Day 2 of admission, Mel is a 50-year-old female, who was admitted to hospital,” “In a hospital setting, glucose levels can be managed easily”</td>
<td>63 (1.7)</td>
<td>1,21,22</td>
</tr>
<tr>
<td>Gather information from references</td>
<td>“Just now look at the therapeutic guidelines to see what they say about Crohn's disease,” “I'm gonna check the dose of that in the AMH.&quot;</td>
<td>435 (11.7)</td>
<td>Inductive b</td>
</tr>
<tr>
<td>Clarify patient case information from facilitator</td>
<td>“I would ask the doctor have the medications been changed since she was admitted in terms of the levetiracetam and carbamazepine.”</td>
<td>458 (12.4)</td>
<td>21</td>
</tr>
<tr>
<td>Review available provided notes</td>
<td>“I would look at the patient admission notes”</td>
<td>276 (7.5)</td>
<td>21</td>
</tr>
<tr>
<td>Processing information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distinguish between relevant and irrelevant information</td>
<td>“I would also like her weight and her height information as well so I could calculate her renal clearance,” “I am going to disregard this interaction since she has been on the medication for a while”</td>
<td>148 (4.0)</td>
<td>21</td>
</tr>
<tr>
<td>Identify precipitants to current problems</td>
<td>“AKI most likely is what have caused the delirium,” “I guess I’m just thinking that the mycophenolate is contributing to her febrile neutropenia”</td>
<td>66 (1.8)</td>
<td>19,20</td>
</tr>
<tr>
<td>Match condition to its characteristic</td>
<td>“Okay, blood pressure, 130, she probably is not going through sepsis at this point”</td>
<td>56 (1.5)</td>
<td>Inductive</td>
</tr>
<tr>
<td>Match problem to management plan</td>
<td>“It seems they’re on prophylactic trimethoprim for UTI,” “There is no prophylactics for any opportunistic infection”</td>
<td>74 (2.0)</td>
<td>Inductive</td>
</tr>
<tr>
<td>Match a therapy with its characteristics</td>
<td>“In regards to the gentamicin though, I can see here that the dose for this one depends more on the weight,” “The aspirin needs to be stopped because it would increase the bleeding further”</td>
<td>133 (3.6)</td>
<td>Inductive</td>
</tr>
<tr>
<td>Recognize differences between abnormal and normal</td>
<td>“Her blood pressure is 130 over 80. That’s like, a little high but still normal-ish,” “The dose of the mycophenolate sodium is too high.”</td>
<td>129 (3.5)</td>
<td>21</td>
</tr>
<tr>
<td>Making assessments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make assessment regarding disease state</td>
<td>“Normal, okay. So there’s no sign of infection,” “I’ve just realized that, if they’ve got pyelonephritis, their kidney function is probably somewhat more impaired, possibly”</td>
<td>94 (2.5)</td>
<td>1,19</td>
</tr>
<tr>
<td>Make assessment regarding therapy: MRP</td>
<td>“She was charted 1000mg twice daily which is, uh, the dose is too high,” “Because aspirin can thin his blood and if he is currently having a haemorrhagic stroke then it can make his bleeding in his brain worse”</td>
<td>99 (2.7)</td>
<td>1,19</td>
</tr>
<tr>
<td>Make assessment regarding therapy: other</td>
<td>“PPI has been ceased, and changed to Ranitidine”</td>
<td>186 (5.0)</td>
<td>Inductive</td>
</tr>
</tbody>
</table>

(Continued)
as selecting the patient-related parameters required for identifying the current problem and sorting out relevant medication-related information from references. This action sometimes co-occurred with clarifying patient case information from the facilitator (similar to searching a medical record), which was when students inquired about the patient in a planned and structured manner. For example, when students knew that they had to calculate creatinine clearance, they proceeded to ask for the patient’s weight, serum creatinine, and height.

To help identify medication-related problems, students matched problems to therapy, matched condition to its characteristics, matched therapy to its characteristics. Matching problems to management plan (e.g., hypertension to hypertension medications) rarely happened in the beginning of the therapeutic reasoning process. This most often occurred after gathering and retrieving information or at a final recommendation stage when the student provided a rationale for choosing a therapy. Matching conditions to its characteristics included disease state diagnostic criteria, risk factors, pathophysiology, and more. Matching therapy to its characteristics included knowledge of side effects, contraindications, dosing, formulations, and more. Students were matching therapy to its characteristics when rationalizing and formulating a plan, making assessments about the therapy, and identifying precipitants to the current problem.

For the next theme, making assessments, students made assessments regarding the disease states to confirm or eliminate diagnoses, to comment on the progress of the disease, and to assess the risk of certain medical problems. They also routinely made general assessments regarding therapy. This process involved constructing a hypothesis about the potential problem, noting changes in the drug regimen, verifying a necessary therapy, and eliminating possible medication-related problems. Eventually, the students would arrive at making assessments regarding medication-related problems, which is the integral component of the mock cases. They identified the problems through actively reviewing the medication charts, pursuing a hypothesis, or relating references to patient-specific factors.

Regarding the themes synthesizing information and articulating evidence, in those students that were able to postulate a potential medication-related problem, they also would then articulate evidence for their assessments.
by citing either their knowledge or evidence from guidelines. Very rarely did students synthesize information before making recommendations. A few rare examples are included in Table 1 and Table 2.

Finally, the last cognitive process theme, making a recommendation, occurred when students, after identifying the problems, determined the optimal therapy for the patient. But before arriving at the final recommendation, they sometimes gave potential management options, which is an action that occurred throughout the therapeutic reasoning process. In some instances, the management options would change as the students reviewed more references. However, most students would follow one potential recommendation while still articulating the evidence for the plan, and it would become the final recommendation. At the phase of giving a recommendation, students rarely compared and contrasted between different options.

For the metacognitive processes, we observed two major metacognitive process themes: monitoring and controlling processes. Regarding monitoring, students expressed self-regulated monitoring of the cognitive tasks, also known as monitoring cognition, which involved describing an awareness of the various components of the decision-making process. In some instances, students commented on their degree of familiarity (or lack thereof) with a piece of data. Students also reflected on potential new therapeutic recommendations that they had generated. The most frequent metacognitive monitoring process observed was students making judgments about their problem-solving process, by taking a step back and evaluating the whole picture. The students commented on whether they felt like they were missing something, focusing too much on one aspect, were lost, or were confused. Often students were not satisfied in their problem-solving process until they

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive monitoring</td>
<td>Monitoring cognition</td>
<td>“I’m not sure if that’s old enough to be a risk factor for delirium but I’m thinking maybe it is,” “I have no clue,” “I think I have to go back,” “I feel like I’ve missed something,” “Okay now I am sure and can present my recommendation”</td>
<td>257 (6.9)</td>
</tr>
<tr>
<td></td>
<td>Metacognitive controlling</td>
<td>Control for cognition: decide next steps</td>
<td>“The first thing I would do would be to go look at her med chart,” “I will go to, erm, MIMS® and I will look for the interactions between ranitidine, carbamazepine and levitic, levetiracetam as well,” “We want to try and figure out what could have caused her delirium”</td>
</tr>
<tr>
<td></td>
<td>Control for cognition: double-check</td>
<td>“I would go on MIMS®, make sure there are no interactions,” “56 years old. I might just double-check, but I doubt they’d be pregnant,” “I’m doing a final check of the guidelines.. before I present my recommendation.”</td>
<td>83 (2.2)</td>
</tr>
<tr>
<td></td>
<td>Control for cognition: investigate unknowns</td>
<td>“I’m just looking at um, the dosage to see whether there’s anything that’s accumulated, presenting similar symptoms,” “I will go on AMH® calculator and estimate her creatinine clearance”</td>
<td>246 (6.6)</td>
</tr>
<tr>
<td></td>
<td>Control for cognition: verify correct information</td>
<td>“Observations said blood pressure is a 120 on 80, which seems fine,” “Um, so right now I’m thinking okay well, if it’s 90 micromoles, then that’s fine,” “doses look fine for that”</td>
<td>46 (1.2)</td>
</tr>
</tbody>
</table>
identified at least one medication-related problem. Another manifestation was students reviewing what they had already completed (e.g., already checked a pain score). Students frequently monitored their cognition while locating information in electronic resources. Near the end of the interactions, some students monitored that they were ready to make a final recommendation.

In the metacognitive theme of controlling cognition, in contrast to monitoring cognition, students expressed metacognitive processes that regulated their strategy to approach the therapeutic reasoning task. This was referred to as control for cognition. Students used metacognitive processes to decide next steps aimed at bridging the gap between a goal and the current progress toward that goal. Goals included establishing the cause of the problem, treatment targets, or what resource should be used next. Similar to deciding next steps, investigating unknowns, which occurred when students lacked a crucial piece of knowledge, could relate to the bigger picture (i.e., patient goal of care), or could be an immediate response to the on-the-spot missing piece of information. Students used double-checking as an attempt to regulate knowledge and as a strategy to increase certainty. In the middle of the decision-making process, students would typically verbalize double-checking a piece of information already received by revising the available notes, asking the facilitator the same question twice, or checking references. The double-checking process was also articulated by several students at the end of the therapeutic reasoning process to decide whether they were ready to make a decision. For example, when students had provided a potential management option, students double-checked a reference to confirm their decision. Verifying correct information is a metacognitive process used when students actively summarize and reflect on their findings. In some instances, students verified information from two sources simultaneously, such as patient-related information and medication/medical data from their bank of knowledge or references to make a quick assessment and eliminate basic problems.

While student cognitive and metacognitive processes varied in terms of the frequency of codes, we were still able to reconcile the sequences and co-occurrences between cognition and metacognition. As a result, we developed a model (Figure 1) to characterize the relationships between the codes.

When major codes were sequenced by the coders, student therapeutic reasoning processes occurred in three main phases, namely gathering and reviewing information, analyzing information, and formulating a hypothesis. However, the three phases are not linear, and students tended to move back and forth between them. In the first phase, gathering information was a cyclical process where

![Figure 1. Proposed integrated model of therapeutic reasoning in students. Key: White boxes (analytical process codes), gray boxes (metacognitive process codes).](#)
students searched for new information, alternating between reading patient notes, asking the facilitator, and inquiring references. Co-occurrence analysis showed an overlap between this phase and three control metacognitive process codes: deciding next steps, investigating unknowns, and double-checking.

Alternating with the phase of gathering information was analyzing information. Using the data gathered in the first phase, students would match characteristics about conditions or therapy and would postulate on potential precipitants of the current problem. The metacognitive code that commonly co-occurred at this stage was monitoring problem-solving as a means of self-affirming their progress or the soundness of their judgments.

The metacognitive code for verifying correct information frequently co-occurred with the analytical process of recognizing between normal and abnormal values. We found that in some cases, students were able to make quick judgments, especially about blood pressure, and were able to confirm that the observation was normal or abnormal.

In some instances, students would remain in the gathering and reviewing stage and would cycle through the various analytical processes with metacognitive co-occurrences. Only students who were able to analyze the information gathered (eg, match therapy with its characteristics) could then progress to the stage of formulating a hypothesis.

In those students who were able to articulate potential management options (n = 38), the metacognitive process of monitoring for sufficient information often occurred, which opened two pathways. If the decision-makers self-assessed that they had the required data to make a decision, they would give a final recommendation. But if they expressed uncertainty, they would double-check their work and go through the gathering information stage again until they felt ready to reach a final decision.

**DISCUSSION**

This study represents the first time, to our knowledge, that the cognitive and metacognitive analytical processes that pharmacy students demonstrate during therapeutic reasoning activities have been explored. When completing tasks that required therapeutic reasoning, pharmacy students displayed a range of cognitive analytical and metacognitive processes. The cognitive processes observed were analytical, involving the gathering of information from references and clarifying information from the facilitator. This is consistent with prior research. Studies involving dual process theory have suggested that novices more commonly depend on systematic analytical processes as opposed to intuitive nonanalytical processes. It is postulated that experts develop richer cognitive structures of knowledge about conditions (“illness script”) and therapies (“therapy script”) such that they become an automatic resource when making clinical decisions.

In this study, we were unable to analyze the presence of nonanalytical cognitive processes, as these were, by definition, unavailable for introspection. However, we did note that in comparison to codes for gathering information, codes for matching a therapy to its characteristic (eg, side effects) was much less frequently observed. This may, in part, suggest a deficiency in well-formed therapy scripts or similar cognitive structure about a medication. We observed that students who failed to match therapy or conditions to prior knowledge (ie, the analyzing information phase) often came to an impasse and cycled repeatedly in the gathering and reviewing information phase of reasoning. For example, in the transplant case, students might have discovered that a medication dose was incorrectly converted (recognizing between normal and abnormal values), but they also needed to know that this could result in medication-induced neutropenia (matching therapy to its characteristics) to identify the primary cause (identify precipitant).

Our research focused on categorizing therapeutic reasoning processes engaged by pharmacy students. Further research is warranted to determine whether particular patterns of observed cognitive or metacognitive processes correlate with the ability to make sound therapeutic decisions and to make these efficiently. Additional factors that may have contributed to therapeutic reasoning error and warrant further investigation include patterns of cognitive biases such as premature closure. We also recommend further exploration linked to specific educational methods to determine which interventions targeted at strengthening deficient or inefficient processes can improve student performance. A scoping review by Daniel and colleagues suggests that there are numerous assessment methods that align with different components of, using their terminology, clinical reasoning. Using this as a guide, we recommend stronger consideration of how non–workplace-based assessments, assessments in simulated clinical environments, and workplace-based assessments provide a complementary approach to feedback on therapeutic decision-making skills. Additionally, aspects of metacognition that went undetected in our study, such as reflection on heuristics or forethought, can be an area for future research. Also, as we were unable to capture nonanalytical processes in a think-aloud protocol, future researchers should measure and test nonanalytical processes.

Unlike most proposed models of pharmacist therapeutic reasoning, students rarely followed the sequence of therapeutic reasoning steps in a stepwise, linear fashion. Students in our study commonly moved back and forth
between major reasoning steps, often with the influence of overlapping metacognition. Student cognitive and metacognitive processes were more scattered than has been depicted in established models. Although we were examining performance at one time point, educators could use process diagrams (such as Figure 1) to show students how experts make therapeutic decisions and how their processes can become more effective and efficient over time.

In previous research about reasoning, metacognitive processes have seldom been explored. Our study findings, in keeping with an integrated dual processing model of reasoning, categorized the importance of metacognition as a mediator for students as they moved between major cognitive analytical processes. For example, in our study it was commonly observed that a controlling metacognitive process of performing a double check influenced students to return to analytical processes of gathering and reviewing information after postulating an initial recommendation. The impact of metacognition on student performance of longer learning periods has demonstrated variable results. Studies have explored the value of metacognition on student academic performance in pharmacy education. Other studies have suggested that strengthening learners’ metacognitive processes may assist in improving clinical reasoning. Teaching strategies that harness metacognitive processes (eg, intentional questioning, modeling techniques, and reflection) may also improve students’ therapeutic reasoning skills. Prior work describing the value of making expert thinking visible to students via a cognitive apprenticeship model can help educators feel more comfortable employing these techniques.

Unlike other models of pharmacist decision-making, students did not routinely consider multiple reasoned options before committing to a therapeutic recommendation. One interpretation of this observation could be that pharmacy students are developing a more decisive pattern of decision-making. On the other hand, it may also be indicative of cognitive biases such as premature closure. In premature closure bias, an individual may accept a therapeutic recommendation prematurely without considering the case information provided or information available from references. However, it must be acknowledged that since this was a think-aloud study whereby students were permitted 60 seconds before prompting to think aloud, some thinking processes, including the consideration of different options, may not have always been articulated by the student and, therefore, not accessible to the investigator. This may be particularly salient, given that students performed this activity among a group of their peers and may not have wanted to share some of their initial, potentially incorrect solutions for fear of embarrassment. For some students, they directed their process toward identifying one medication-related problem. This naïve approach could be the result of the constraints of our activity design, which, out of respect for time, often involve only one medication-related problem. More research needs to be performed to explore the presence of potential cognitive biases inherent in the reasoning processes of pharmacy students. Also, future researchers should explore how students’ therapeutic reasoning processes develop over time. It is possible that these students will learn how to prioritize and synthesize their thinking as they are exposed to more visible demonstrations of therapeutic decision-making as their formal training continues.

Several limitations can be applied to our study results. Concurrent verbalization of thoughts while performing the activity can disrupt decision-making processes. This limitation similarly applies to think-aloud studies of pharmacists performing a dispensing task. This limitation is particularly salient when students are engaging in complex tasks that involve integrating knowledge and problem. Furthermore, in our study students were permitted to clarify further information from the facilitator about the case as required. While facilitators were instructed to only encourage thinking aloud during the activity, their presence in the activity may have encouraged students to seek their opinion and clarify information more than they would have if students had to complete the task independently. Similarly, due to logistical constraints, students were asked to perform the think-aloud session in front of their team within a finite period (15 minutes). Although the activity was formative in nature, added pressures of time and peer observation may have also influenced the observations.

CONCLUSION
This study describes the cognitive analytical and metacognitive processes pharmacy students demonstrate when making therapeutic decisions. The proposed model that overlays the key cognitive processes (ie, gathering and reviewing, analyzing information, formulating a hypothesis) and metacognitive processes (eg, deciding next steps, investigating unknowns, and double-checking) highlights the nonlinearity of the novice approaches. It also suggests specific steps (eg, matching) that can cause bottlenecks in their progression.

The findings will inform educators about how to design programs that specifically introduce, practice, and provide feedback on these processes in the classroom, via simulation, and in the clinical setting. Showing students where they are struggling on this integrated model could help to nudge them toward making more effective and efficient therapeutic decisions. For example, using the
think-aloud activity itself could help delineate the therapeutic reasoning skills of the individual as compared to a general expected model of pharmacy students. In this sense, the model proposed can help serve as a foundation for further research into which education strategies best support the development of potentially deficient cognitive or metacognitive processes that impede successful therapeutic decision-making. This could also serve as a tool to diagnose therapeutic reasoning performance and provide opportunities for remediation.

ACKNOWLEDGEMENTS

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